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Exploration of Geometry Concepts in the Architecture of the Grand Mosque of Sultan Thaf Sinar Basarsyah as a Mathematics Learning Media

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Abstract
Ethnomathematics is the study of how people from different cultures understand, interpret, and use mathematical concepts. Meanwhile, various studies have highlighted the beauty and symbolism of geometric aspects in mosque architecture, but there are still limited studies examining how these geometric elements can be used as learning media. This study aims to explore geometric concepts in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque and examine its application as a contextual mathematics learning resource. The methods used include direct observation, semi-structured interviews, and visual documentation with a descriptive qualitative approach. This study uses an interactive model data analysis technique proposed by Miles and Huberman (1994). The results show that the mosque building contains geometric elements such as circles, semicircles, squares, rectangles, rhombuses, and cylinders that have cultural symbolic meaning and religious aesthetics. This study recommends that mathematics learning increasingly utilize architectural heritage as an interesting and educational learning medium, thereby strengthening cultural identity while supporting the development of mathematical conceptual abilities in a more contextual and meaningful manner.

Keywords: Geometry Concept, Mosque Architecture, Learning Media

1. Introduction

Mathematics is a branch of science that studies quantities, shapes, and interrelated concepts. In the current curriculum, mathematics instruction emphasizes learning that facilitates students' ability to solve mathematical problems. Mathematical problems that directly involve real objects can be transformed into contextual story problems, which are characteristic of mathematical problems. However, mathematics is often considered a boring or difficult subject for some students

(Adhiyati et al., 2022). Various factors contribute to this, including monotonous teaching methods, lack of student motivation and interest in learning, suboptimal classroom learning processes, and a lack of connection between mathematics and contextual problems (Ardiansyah et al., 2022).

Ethnomathematics was introduced by D'Ambrosio, a Brazilian mathematician, in 1977. D'Ambrosio defined ethnomathematics as mathematics practiced among cultural groups, identified as national communities, labor groups, children of certain age groups, and professional classes (Ajmain et al., 2020). The combination of culture and mathematics is very beneficial for life when combined. Mathematics is always related to every aspect of social interaction throughout the world. Real and relevant mathematics learning for students can be realized by linking mathematical concepts to their culture or life context, which originates from their ancestral culture (Amelia et al., 2024). Ethnomathematics can be said to be similar to realistic learning, because it also provides concrete examples, namely the culture in the surrounding environment, as material for mathematics learning. Students can better understand various mathematical concepts through the building of the Sultan Thaf Sinar Basarsyah Grand Mosque, which also has aesthetic value.

Geometry is a branch of mathematics that is abstract in nature. Another opinion regarding geometry is expressed by Susanto (2021), who states that geometry is a branch of mathematics that connects mathematics with real-world contexts or everyday life. Geometry in mathematics studies points, lines, angles, planes, space, and two forms of geometry: plane and solid (Hamzah et al., 2014). Learning geometry requires many contextual examples for easier understanding. For example, illustrating mathematical concepts through visualization of real images, sketches, or building forms that can be seen concretely in everyday life (Yulianti, 2016). By understanding geometric concepts, everyone gets help in describing and visualizing forms in real life.

This study utilizes the geometric elements contained in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque as a medium for learning mathematics. This research combines semiotic analysis (the analysis of the symbolic meaning of architectural forms) with mathematics learning design. In this way, the developed media not only helps students understand mathematical concepts but also introduces the cultural values and local context behind these forms. This contrasts with previous research by Alifia Zahra Shafira et al. (2024), which focused more on the aesthetic, symbolic, or cultural meanings of mosque architectural forms. Their findings were rich in aspects of meaning and cultural context, as well as how architectural forms convey symbolic messages to the community. However, that study did not further translate these semiotic findings into concrete educational products or teaching media.

While various studies have highlighted the beauty and symbolism of geometric aspects in mosque architecture, there are still limited studies examining how these geometric elements can be used as learning media. Most studies focus more on aesthetic analysis and symbolic meaning without integrating an understanding of the direct application of geometric elements in mosques in mathematical learning activities that actively motivate students. Furthermore, there is still little research developing learning models based on mosque architecture as a learning resource that can connect abstract mathematical concepts with real-life experiences through digital technology methods, so the opportunity to enrich geometry teaching contextually remains wide open. Therefore, research is needed that broadens insight into the potential use of geometric elements in mosque architecture as a learning medium that can improve understanding of mathematical concepts while strengthening appreciation for cultural heritage.

Mathematics learning media based on mosque architecture, particularly the geometric elements contained within, have great potential to enhance the understanding of mathematical concepts in a contextual and relevant manner. Mathematics learning requires a learning model that can engage students and maximize their abilities (Yustinaningrum et al., 2022). The use of geometric shapes such as circles, squares, and cylinders in mosque buildings not only enriches the aesthetic and cultural aspects but also serves as an effective learning resource, given that the buildings can directly explain mathematical concepts through observation of real objects (Fitri, 2023). This approach supports culture-based contextual learning, which can increase students' interest and motivation in understanding mathematical concepts, while strengthening their cultural identity and spiritual character. The integration of geometric elements into architecture as a learning medium is expected to bridge mathematical abstraction with everyday reality and provide a more vibrant and meaningful learning experience (Harahap, 2022).

Furthermore, there has been little in-depth exploration of the application of geometric shapes in mosque architecture as an effective learning resource, as well as its influence on students' understanding of mathematical concepts and motivation (Rahman et al., 2023). Thus, there is an urgent need for a more comprehensive study of how geometric elements in mosque architecture can be integrated into mathematics learning to enhance conceptual understanding and foster cultural and religious appreciation among students (Rosa et al., 2016).

Mosques, as places of worship for Muslims, possess extraordinary architectural richness. Elements such as curved domes, towering minarets, and regular, symmetrical ornaments and carvings are clear examples of the application of geometric concepts (Nasution et al., 2021). The beauty and philosophy behind the mosque's structure make it a learning medium that is not only educational but also enriches cultural and spiritual insights.

This research also supports efforts to preserve Islamic culture and architecture through education. By introducing geometric elements in Islamic architecture to students, education also plays a role in cultural preservation. The younger generation is expected to develop an awareness of the importance of cultural and scientific values inherited from their ancestors (Ali, 2015). Through this learning, students are encouraged to learn more than just mathematics but also to recognize and appreciate the history and culture inherent in the building.

2. Methods

This research uses a descriptive qualitative method with a case study approach to explore the geometric concepts contained in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque and its application in mathematics learning. This method was chosen because it allows researchers to understand and describe phenomena in depth based on data collected from various sources. Mosque administrators were selected as research informants due to their strategic role and in-depth knowledge of mosque planning, management, and maintenance. Therefore, the selection of mosque administrators as informants was deemed appropriate, relevant, and capable of supporting the achievement of the research objectives. According to Moleong (2018), qualitative research aims to understand phenomena that occur in a natural context, where researchers act as the main instrument in collecting and analyzing data. The case study in this research focuses on the analysis of geometric elements in the architectural design of the Sultan Thaf Sinar Basarsyah Grand Mosque and how these concepts can be used in culture-based mathematics learning.

This study uses the interactive model data analysis technique proposed by Miles and Huberman (1994), which consists of three main stages: data reduction, data presentation, and conclusion drawing/verification. This data reduction aims to eliminate irrelevant information and clarify the main aspects being studied. This data presentation allows researchers to see the relationship between geometric elements in buildings and mathematical concepts that can be applied in learning. Conclusions are obtained by interpreting the findings compiled in the previous stage, then linking them to geometric theory in mathematics and its application in culture-based learning.

Data collected from various techniques were analyzed using data triangulation, namely by comparing and confirming the results of observations, interviews, and documentation to ensure the accuracy and validity of the research findings. This triangulation technique was used to draw more objective conclusions regarding the relationship between geometric concepts in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque and their application in mathematics learning. After data analysis, the research results are presented in the form of a systematic description that illustrates how exploring geometry in architecture can be an innovative strategy for improving students' understanding of culture-based mathematics concepts (Ulya et al., 2020).

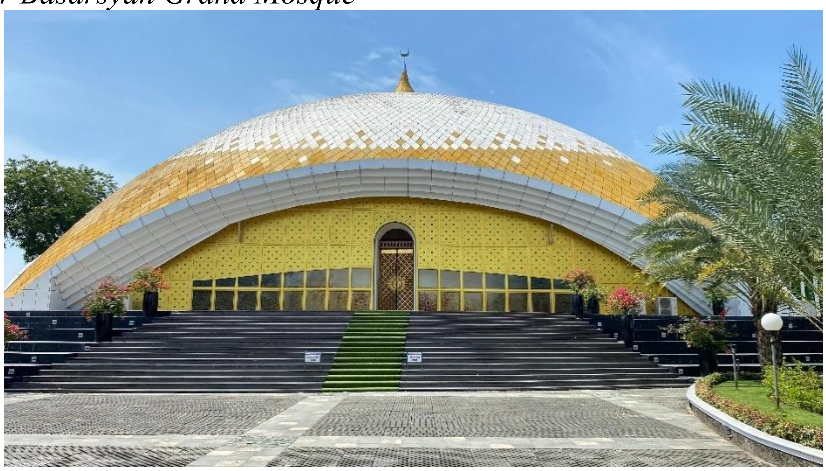
3. Result and Discussion

This research demonstrates that the Sultan Thaf Sinar Basarsyah Grand Mosque possesses a rich array of architectural elements imbued with geometric concepts. Observations and documentation revealed that geometric shapes such as circles, squares, triangles, and various geometric shapes are frequently found throughout the building. This demonstrates that the mosque serves not only as a place of worship but also holds educational values that can be used as learning resources, particularly in mathematics.

The research results are presented objectively based on field findings, while the discussion section contains analysis and interpretation of the results, linking them to theory and previous research. The implications of these findings for mathematics learning include the availability of contextual learning resources that help students understand geometric concepts more concretely and meaningfully through the surrounding cultural context. Meanwhile, in curriculum design, these findings encourage the integration of an ethnomathematics approach by incorporating local architecture as a learning context, thereby making the curriculum more relevant, contextual, and able to connect mathematical concepts to cultural values and students' real lives.

This study shows that geometric elements are clearly visible in the architectural elements of the Sultan Thaf Sinar Basarsyah Grand Mosque and can be used as a medium for contextual mathematics learning. An international study by Abdullahi (2009) shows that in traditional Islamic architecture in the Middle East and North Africa, symmetry and geometric proportions are also the main principles for creating visual order and symbolic meaning. Similarly, Critchlow (1976) explains that geometric patterns in mosque architecture globally are not merely decorative, but have a systematic mathematical structure that is relevant for learning mathematical concepts. This comparison confirms that local findings do not stand alone, but are consistent with international architectural design patterns that use geometry as a structural and aesthetic element and have pedagogical potential in the context of mathematics education.

Figure 1.
Sultan Thaf Sinar Basarsyah Grand Mosque



The subject of this study was a mosque administrator, Mr. JH, currently 52 years old. He has served as the caretaker and caretaker of the Sultan Thaf Sinar Basarsyah Grand Mosque for 11 years. During his more than a decade of service, Mr. JH is known for his meticulous and responsible nature. With his experience and diligence, Mr. JH has become a vital part of the mosque's operations, where his presence not only fulfills technical functions but also reflects the values of sincerity and genuine service for the continuity of Muslim worship activities at the Sultan Thaf Sinar Basarsyah Grand Mosque.

The data collection techniques used in this study included direct observation of the mosque site, semi-structured interviews with the mosque administrator, Mr. JH, and visual documentation of various elements of the mosque's structure. Through the interviews, researchers obtained information about the design philosophy, aesthetic principles, and religious values underlying the mosque's construction. Meanwhile, observations and documentation were conducted to identify geometric shapes appearing within the building and their potential use as a learning tool for mathematics.

Using an ethnomathematical approach, shapes such as rectangles, rhombuses, equilateral triangles, and sectors of a circle are found scattered throughout various parts of the mosque. For example, the shape of a mosque window, which resembles an arc of a circle or other curved shape, can be used to introduce the concepts of arc length and sector area. Through this contextual approach, students learn not only through pictures in textbooks but also through direct observation of real objects containing mathematical elements.

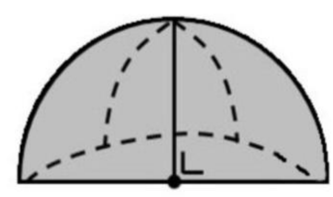
The main elements successfully documented include domes, minarets, pillars, doors, drums and kentung (a kind of musical instrument), roof lamps, mihrab (a kind of prayer niche), and mosque stairs. Each element was analyzed based on two aspects: its apparent geometric shape and its potential use in mathematics learning. A detailed description of these elements will be presented at the end of this chapter.

Based on the data obtained, it can be concluded that the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque contains many geometric concepts relevant to mathematics learning. By utilizing this building as a learning medium, students can more easily understand abstract concepts through tangible objects that can be directly observed.

3.1. The shape of the mosque dome

Figure 3.1.

Dome of the Sultan Thaf Sinar Basarsyah Grand Mosque

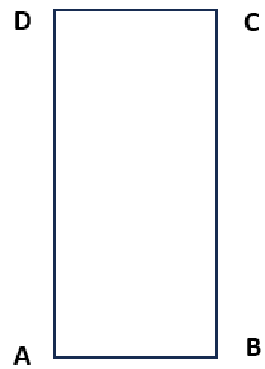


In figure 3.1 is a picture of the dome of the Sultan Thaf Sinar Basarsyah Grand Mosque which is in the form of a half ball (hemisphere), namely a three-dimensional geometric shape which is half of a full sphere with a perfectly curved surface where all points on the surface are equidistant from the center point. The hemispherical shape of the dome is seen from the symmetrical curve that curves fully from the top point to the bottom edge, with geometric elements such as the center point O, the radius r that connects the center point to the edge of the dome, and the diameter that stretches through the center point from one side to the other. The formula for the surface area of a half ball is $L = 3\pi r^2$, while the volume is $V = \frac{2}{3}\pi r^3$, which can be used as a medium for learning mathematics to introduce the concept of curved geometric shapes, the relationship between diameter, radius, surface area, and volume, as well as understanding the application of these concepts in Islamic architecture that combines aesthetic, structural, and symbolic functions.

3.2. Tower Shape

Figure 3.2.

The Tower of the Grand Mosque of Sultan Thaf Sinar Basarsyah

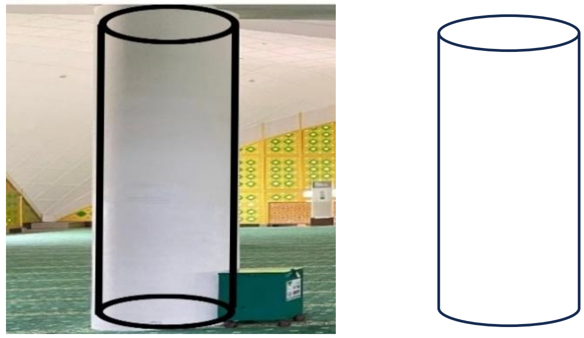


In figure 3.2 is a picture of the tower of the Sultan Thaf Sinar Basarsyah Grand Mosque which has a basic rectangular shape that extends vertically. A rectangle is a quadrilateral plane shape that has two pairs of parallel and equal sides, and its four corners are right angles. The rectangular elements in this tower are seen on the parallel base and top sides, where side AB is parallel and equal in length to side CD, and side AD is parallel and equal in length to side BC. The formula for the perimeter of a rectangle is $K = 2\,(p + l)$ and its area is $L = p \times l$. The rectangular shape of this tower can be used as a medium for learning mathematics to understand the concept of plane shapes, the relationship between length, width, perimeter, area, and diagonals, while also showing the real application of geometric concepts in Islamic architecture that combines the firmness of form, structural strength, and visual beauty.

3.3. Pillar Shape

Figure 3.3.

Pillar of the Sultan Thaf Sinar Basarsyah Grand Mosque



In figure 3.3 is a picture of the pillar of the Sultan Thaf Sinar Basarsyah Grand Mosque which has a basic cylindrical shape. A cylinder is a three-dimensional geometric shape that has two parallel and congruent circular base planes, and one curved rectangular covering plane surrounding both bases. The elements of the cylinder in this pillar are seen in the parallel circles of the lower base and the upper base, with a radius r connecting the center point of the base to the edge of the circle, and a height t which is the perpendicular distance between the two bases. The formula for the surface area of a cylinder is $L = 2\pi r\ (t + r)$and its volume is $V = \pi r^2\ t$. This pillar shape can be used as a medium for learning mathematics to understand the concept of cylindrical geometric shapes, including the relationship between radius, height, surface area, and volume, while also showing the real application of geometric concepts in Islamic architecture that combine structural strength, aesthetics, and symbolic meaning.

3.4. Door Ornaments

Figure 3.4.

Door Ornaments of the Sultan Thaf Sinar Basarsyah Grand Mosque

In figure 3.4 is a picture of the door ornament of the Sultan Thaf Sinar Basarsyah Grand Mosque which has a basic rhombus shape. A rhombus is a quadrilateral whose four sides are the same length, has two pairs of opposite angles that are equal, and the two diagonals intersect at right angles and bisect each other equally. The elements of the rhombus in this door ornament are seen in the four sides AB, BC, CD, and DA which are the same length. The area formula is $L = \frac{1}{2} \times d_1 \times d_2$, while the perimeter can be calculated with the formula $K = 4 \times s$, where s is the length of the side. This rhombus ornamental shape can be used as a medium for learning mathematics to understand the properties of flat shapes, the relationship between diagonals, and the application of geometric concepts in Islamic architectural art that combines aesthetic values, precision, and symbolic meaning.

3.5. Bedug and Kentung Shape

Figure 3.5.

Drum and Kentung Shape of the Sultan Thaf Sinar Basarsyah Grand Mosque

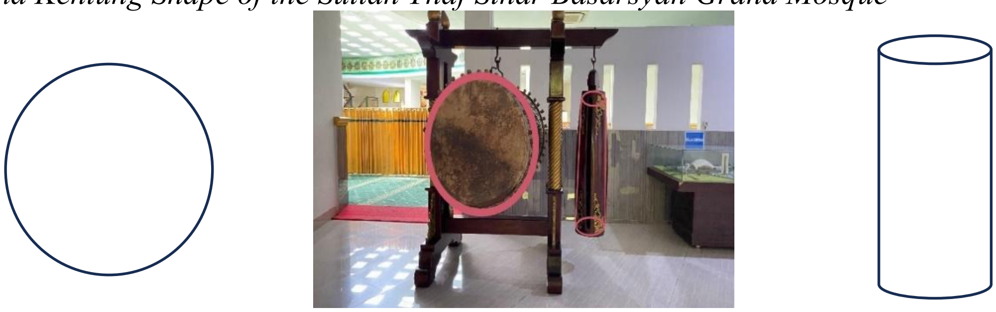


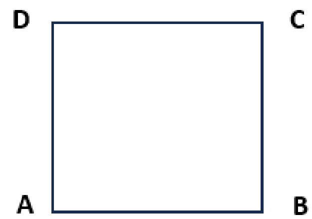
Figure 4.1.5 depicts the drum of the Sultan Thaf Sinar Basarsyah Grand Mosque, which has a basic circular shape on its front. A circle is a plane figure bounded by a set of points equidistant from the center. The elements of a circle in this drum are seen in the center point O, the radius r connecting the center point to the edge of the circle, and the diameter, a straight line through the center point with a length twice the radius. Circles also have arcs, chords, and sectors, which can be analyzed in a geometric context. The formula for the circumference of a circle is $K = 2\pi r$ and its area is $L = \pi r^2$. The circular shape of this drum can be used as a mathematics learning tool to introduce the properties of plane figures, the relationship between radius, diameter, circumference, and area, while also providing a concrete example of the application of geometric concepts in traditional objects that play an important role in Islamic worship.

The image of the kentung of the Sultan Thaf Sinar Basarsyah Grand Mosque has a basic cylindrical shape. A cylindrical figure is a three-dimensional geometric figure with two parallel and congruent circular bases and one rectangular curved surface surrounding both bases. The elements of the cylinder in this kentung can be seen in the circles of the lower base and the upper base which are parallel, the radius r which connects the center point of the base to the edge of the circle, and the height t which is the perpendicular distance between the two bases. The formula for the surface area of the cylinder is $L = 2\pi r(t + r)$and its volume is $V = \pi r^2 t$. The cylindrical shape of this kentung can be used as a medium for learning mathematics to understand the concept of geometric shapes, the relationship between radius, height, surface area, and volume, and provides a real example of the application of geometry to traditional objects that play an important role in Islamic worship activities.

3.6. In Design

Figure 3.6.

Roof Lamp of the Sultan Thaf Sinar Basarsyah Grand Mosque



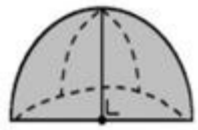
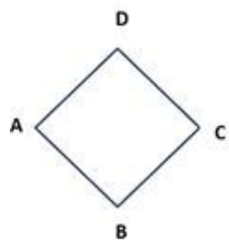
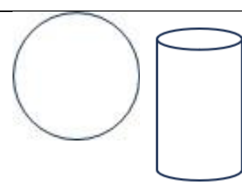
In figure 3.6 is a picture of the roof lamp of the Sultan Thaf Sinar Basarsyah Grand Mosque which has a basic rectangular shape. A rectangle is a quadrilateral plane shape that has four sides and four corners, where the sum of the angles is 360°. The rectangular shape of this roof lamp can be seen on the sides AB, BC, CD, and DA which are connected to each other to form a flat plane, with diagonals AC and BD intersecting each other at point O. If the shape is a rectangle, then the opposite sides are the same length and parallel, while if it is a square, then all sides are the same length and the four corners are right angles. The formula for the perimeter of a rectangle in general is $K = AB + BC + CD + DA$, while the area depends on the type of rectangle, for example a rectangle has the formula $L = p \times l$ and a square has the formula $L = s^2$. The rectangular shape of this roof lamp can be used as a learning medium for mathematics to introduce the properties of plane shapes, perimeter, area, and diagonals, while also showing the application of geometric concepts to the architectural elements of the mosque that function as lighting as well as aesthetic elements.

To clarify the research results related to the geometric forms found in the Sultan Thaf Sinar Basaryah Grand Mosque, the following is a summary of the dominant geometric forms and the mathematical concepts related to each form.

Table 1.

The Geometric Shape of the Sultan Thaf Sinar Basarsyah Grand Mosque

No.	Name of the Shape of the Mosque Building	Geometric Shapes	Formula

1.	The shape of the mosque dome		The formula for the surface area of a hemisphere is $L = 3\pi r^2$, while the volume $V = \frac{2}{3}\pi r^3$.
2.	Tower Shape		The formula for the perimeter of a rectangle is $K = 2(p + l)$ and its area $L = p \times l$.
3.	Pillar Shape		The formula for the surface area of a cylinder is $L = 2\pi r(t + r)$ and its volume $V = \pi r^2 t$.
4.	Door Ornaments		The area formula $L = \frac{1}{2} \times d_1 \times d_2$, while the circumference can be calculated using the formula $K = 4 \times s$,
5.	Bedug and Kentung Shape		Circle: The formula for the circumference of a circle is $K = 2\pi r$ and its area $L = \pi r^2$. Tube: The formula for the surface area of a cylinder is $L = 2\pi r(t + r)$ and its volume $V = \pi r^2 t$.

6.	Roof Lamp Shape		The general formula for the perimeter of a square is $K = AB + BC + CD + DA$, while the area depends on the type of rectangle, for example a rectangle has the formula $L = p \times l$ and the square has the formula $L = s^2$.

3.7. Discussion

An exploration of geometric concepts in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque demonstrates that the building serves not only as a place of worship but also as a work of art filled with geometric elements (Fitriani, 2022). The use of a hemispherical dome confirms that this architecture represents a concrete application of geometric concepts in modern Islamic building design (Yuliana, 2021).

Geometric concepts are directly applied in the mosque's physical structure, such as the dome's shape, which relates to the volume and surface area of a sphere (Harahap, 2022). Furthermore, these architectural elements facilitate contextual mathematics learning, enabling students to understand fundamental concepts such as spatial form (Saputra, 2020). This approach makes mathematics more relevant and meaningful in everyday life (Putri et al., 2021). Therefore, this building serves as an effective medium for introducing mathematical concepts visually and contextually (Mustafa, 2021).

This study utilizes the geometric elements contained in the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque as a medium for learning mathematics. This study combines semiotic analysis (the analysis of the symbolic meaning of architectural forms) with mathematical learning design. In this way, the developed media not only helps students understand mathematical concepts but also introduces the cultural values and local context behind the forms. This contrasts with previous research by Alifia Zahra Shafira et al. (2024) which focused more on the aesthetic, symbolic, or cultural meaning of the mosque's architectural forms. Their findings are rich in aspects of meaning and cultural context, as well as how architectural forms convey symbolic messages to the community. However, this study did not further develop these semiotic findings into concrete educational products or teaching media.

Mosque architecture-based mathematics learning media is discussed as an innovation in effective and contextual learning. The use of audiovisual media in mosque architecture-based mathematics learning can provide a more lively and interactive learning experience. See the following video at the link: https://youtu.be/69yBhyil1mA?si=d44giwCOMvVxKEw5 Students can directly see the relationship between mathematical concepts and real geometric shapes. The use of video allows teachers to display and introduce these elements, thereby enriching the learning experience and facilitating the understanding of mathematical concepts in a concrete and contextual way (Gerdes, 1997). Furthermore, video media can be accessed anytime and anywhere, providing flexibility in the learning process and supporting effective learning that can increase student interest and motivation in learning mathematics based on local culture.

The use of video media in learning can also provide engaging audiovisual experiences, strengthening students memory and understanding of complex material. In the context of mathematics learning, videos can demonstrate the relationship between geometric shapes and cultural philosophy, enabling students not only to understand concepts theoretically but also to apply them in real-life situations. This concept aligns with the principles of ethnomathematics, which emphasize the importance of cultural context in learning mathematics (Hidayat, 2020). Thus, video media serves as an effective tool in delivering material and enhancing the quality of the contextual and meaningful mathematics learning process for students.

A recent study concluded that the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque incorporates geometric elements linked to Islamic philosophy and local culture (Azizah, 2022). The conclusion of a recent study shows that the architecture of the Sultan Thaf Sinar Basarsyah Grand Mosque supports geometric elements with Islamic philosophy and local culture (Azizah, 2022). Theoretically, the findings of this study strengthen the concept of ethnomathematics by showing that mosque architecture contains geometric principles relevant to mathematics learning. Practically, these findings can be used as a basis for developing contextual, culturally based, and more meaningful mathematics teaching materials and media for students. Further research is recommended to expand the study object to mosques or other cultural buildings in various regions and examine their impact on students' conceptual understanding, motivation, and mathematical literacy through experimental approaches or curriculum development.

4. Conclusion

This research shows that the Sultan Thaf Sinar Basarsyah Grand Mosque exhibits numerous architectural forms related to geometric concepts. Shapes such as circles, semicircles, squares, rectangles, rhombuses, and cylinders can be found throughout the mosque. These shapes not only enhance the building's beauty but also possess educational value and meaning that can be linked to mathematics learning. By exploring these geometric elements, mathematics learning can become more engaging as students learn through real-life examples that are close to their lives and culture.

The results of this research also demonstrate that mosque architecture can be used as an effective medium for learning mathematics. The use of this culturally based learning medium can increase students' interest and motivation in learning mathematics, as they learn not only numbers and formulas but also understand the cultural values and beauty behind them. Thus, the Sultan Thaf Sinar Basarsyah Grand Mosque serves not only as a place of worship but also as a learning resource rich in cultural, spiritual, and educational values.

Through direct observation, interviews, and documentation, this research yielded accurate and in-depth data. Qualitative descriptive analysis using the Miles and Huberman interactive model enabled in-depth interpretation of the relationship between architecture and mathematical concepts.

The analysis shows that the architectural forms of mosques can serve as the basis for creating locally based mathematics learning materials, which can help teachers teach geometry concepts in a more contextual way. This type of learning is expected to facilitate students' understanding of mathematics while fostering a sense of pride in their local culture.

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